CAN VOLUNTEERS PICK UP THE SLACK? EFFORTS TO REMEDY KNOWLEDGE GAPS ABOUT THE WATERSHED IMPACTS OF MARCELLUS SHALE GAS DEVELOPMENT

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INTRODUCTION

Since 2008, a natural gas boom has been underway in Pennsylvania and West Virginia, as oil and gas companies are pursuing a source of natural gas that was previously considered too difficult to access—the Marcellus Shale.[1] Activities associated with development of the Marcellus Shale, including the handling of large quantities of hazardous waste water, and land use changes leading to soil erosion and runoff, are likely to pose significant environmental risks and cause contamination of streams, ponds, and other surface water if not managed properly. In response to the relative lack of regulatory or professional monitoring of watershed degradation, private citizens are increasingly taking the task of environmental monitoring into their own hands, forming volunteer watershed monitoring groups and using an array of tests to detect water pollution. Public agencies, such as the Pennsylvania Department of Environmental Protection, and university scientists, such as researchers at Pennsylvania State University, are encouraging these activities as a supplement to monitoring by regulatory scientists and as a source of data for environmental research. Many water

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1. U.S. ENERGY INFO. ADMIN., *Pennsylvania Drives Northeast Natural Gas Production Growth* (Aug. 30, 2011), *available at* http://www.eia.gov/todayinenergy/detail.cfm?id=2870; Jonathan D. Silver, *The Marcellus Boom / Origins: The Story of a Professor, a Gas Driller and Wall Street*, PITTSBURGH POST-GAZETTE, Mar. 20, 2011, http://www.post-gazette.com/pg/11079/1133325-503.stm/.

monitoring groups also believe that their scrutiny will encourage the industry to be on its best behavior.

In this paper, we offer an assessment of this increasingly prevalent model of environmental governance, which relies primarily upon self-funded volunteers to monitor and report environmental impacts. Civil society research[2] appears to offer a promising way to gather environmental data at a time when government agencies are struggling to keep up with a rapidly expanding industry. It is therefore essential to understand the scope of these volunteer projects and to critically consider their role in the larger effort to gather environmental data.

There are good reasons to monitor watersheds for the impacts of Marcellus Shale gas development. The extraction of shale gas is a complex, multi-stage process with environmental impacts that are different from conventional gas drilling. Watershed impacts have been among the top concerns for environmental regulators, local communities, and environmental advocacy organizations. Every stage of the exploration and drilling process, from seismic testing to reclamation, poses its own set of unique watershed and water quality risks. Shale gas extraction operations use a combination of techniques, including horizontal drilling and perforation, and hydraulic fracturing techniques (“hydrofracing” in industry parlance, often called “fracking” by critics). Hydraulic fracturing involves injecting a mixture of water, chemicals, and proppants (such as sand) under very high pressure to cause the shale to fracture and release its gas.[3]

Gas-drilling operations in the Marcellus Shale use an average of 3,000,000 gallons of water in the process of drilling and fracturing a well.[4] Before the fresh water used in the hydraulic fracturing process

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2. The phrase “civil society research” refers to scientific research projects carried out by non-governmental organizations and advocacy groups. David Hess, *The Potentials and Limitations of Civil Society Research: Getting Undone Science Done*, 79 SOCIOLOGICAL INQUIRY 306 (2009).

3. ANTHONY ANDREWS ET AL., CONG. RESEARCH SERV., R40894, UNCONVENTIONAL GAS SHALES: DEVELOPMENT, TECHNOLOGY, AND POLICY ISSUES 22 (2009), *available at* http://www.fas.org/sgp/crs/misc/R40894.pdf.

4. GROUND WATER PROT. COUNCIL & ALL CONSULTING, MODERN SHALE GAS DEVELOPMENT IN THE UNITED STATES: A PRIMER 64 (2009), *available at* http://www.netl.doe.gov/technologies/oil-gas/publications/epreports/shale_gas_primer_2009.pdf; *see also Water Withdrawals for Development of Marcellus Shale Gas in Pennsylvania*, PA. STATE COOPERATIVE EXTENSION 2 (2010), http://pubs.cas.psu.edu/freepubs/pdfs/ua460.pdf.

is injected underground, it is mixed with additives such as friction reducers, biocides, and acids.[5] While these chemicals typically compose less than 0.5% of the hydraulic fracturing fluid by volume, a well that consumes 3,000,000 gallons of water also uses approximately 15,000 gallons of additives, which are transported to well sites to be stored and mixed, and ultimately are part of the liquid waste.[6] Of the water used to drill and conduct initial fracing at a single Marcellus horizontal well, roughly 10 to 30% will return to the surface as "flowback."[7] The remainder of the water and chemical mixture remains underground for an indefinite period of time, returning to the surface throughout the life of the gas well as "produced water."[8]

The flowback and produced water from hydraulically fractured shale gas wells is a "brine" that contains more salt than sea water plus heavy metals and radioactive materials from the geology through which it has flowed.[9] This hazardous waste is collected in ponds at the well site or in holding tanks. The waste water must be treated on-site, at special treatment facilities, or shipped to deep injection wells for long-term disposal. Some operators reuse or "recycle" flowback water in later fracturing jobs. Gas drillers have approached the problem of waste water in a variety of ways and continue to devise new methods of handling the waste;[10] however, a series of accidents

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5. *See* BUREAU OF OIL & GAS MGMT., PA. DEP'T OF ENVTL. PROT., CHEMICALS USED BY HYDRAULIC FRACTURING COMPANIES IN PENNSYLVANIA FOR SURFACE AND HYDRAULIC FRACTURING ACTIVITIES (2010), *available at* www.ohvec.org/issues/marcellus/Frac_list_6_30-2010.pdf (listing a total of seventy-eight different chemicals used for both surface and hydraulic fracturing activities).

6. DANIEL J. SOEDER & WILLIAM M. KAPPEL, WATER RESOURCES AND NATURAL GAS PRODUCTION FROM THE MARCELLUS SHALE 4 (2009), *available at* http://pubs.usgs.gov/fs/2009/3032/pdf/FS2009-3032.pdf.

7. *See* JENNIFER HOFFMAN, SUSQUEHANNA RIVER BASIN COMM'N, NATURAL GAS DEVELOPMENT (2010), *available at* http://www.srbc.net/programs/docs/SRBC%20Science%20of%20the%20marcellus%20012910.pdf (stating an average recovery of 13.5%); JOHN A. VEIL, ARGONNE NAT'L LAB., FINAL REPORT: WATER MANAGEMENT TECHNOLOGIES USED BY MARCELLUS SHALE GAS PRODUCERS 13 (2010), *available at* http://www.ead.anl.gov/pub/doc/Water%20Mgmt%20in%20Marcellus-final-jul10.pdf (claiming that "anecdotal reports from Marcellus operators suggest that the actual percentage is at or below the lower end of [the 30 to 70%] range").

8. GROUND WATER PROT. COUNCIL & ALL CONSULTING, *supra* note 4, at 66–67.

9. Carl S. Kirby et al., *Inorganic Geochemistry of Marcellus Shale Natural Gas Hydrofracturing Waters*, 42 GEOLOGICAL SOC. AM. ABSTRACTS WITH PROGRAMS 556, 556 (2010).

10. VEIL, *supra* note 7, at 13.

and spills in Pennsylvania suggests that wastewater is not always being handled safely.[11]

The public is dependent on regulatory agencies—and to a lesser extent, on academic researchers—to monitor environmental contamination resulting from natural gas drilling and to provide pertinent risk information. However, the public is often dissatisfied with the knowledge produced by public agencies and academic institutions, and, as a result, volunteer watershed monitoring has emerged. In part I below, we begin with a discussion of how to conceptualize absences of knowledge about the impacts of gas development. Part II summarizes the known environmental hazards of natural gas development and identifies some of the areas for which regulators and scientists lack adequate information. Part III addresses the emergence of volunteer watershed monitoring as a method of filling knowledge gaps and providing knowledge that satisfies public needs. Finally, part IV assesses the possible benefits and limitations of volunteer monitoring and considers whether it has the potential to change industry behavior, as many volunteers hope that it does.

I. UNDERSTANDING ABSENCES OF KNOWLEDGE

Science policy scholars have noted that there is often a "mismatch between the knowledge that science generates and the knowledge society needs," resulting in public discontent with expert knowledge.[12] Regulatory experts often disagree with civil society organizations about the importance of increasing the commitment of resources to research, or "knowledge investments," in particular areas and the adequacy of the science used in environmental decision-making and risk communication.[13] Such conflicts are widespread. For

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11. *See Seeps, Leaks & Spills*, MARCELLUS-SHALE.US, http://www.marcellus-shale.us/seeps_leaks_spills.htm (last visited Jan. 30, 2012) [hereinafter *Seeps, Leaks & Spills*] (describing a variety of chemical spills or leaks); ERIKA STAFF, PENN ENV'T RESEARCH & POL'Y CTR., RISKY BUSINESS: AN ANALYSIS OF MARCELLUS SHALE GAS DRILLING VIOLATIONS IN PENNSYLVANIA 2008–2011, at 1 (2012), *available at* http://pennenvironmentcenter.org/sites/environment/files/reports/Risky%20Business%20Violations%20Report_0.pdf (describing a total of 3355 violations of environmental laws by 64 different gas-drilling companies, 2392 of which posed a direct threat to the environment, between January 1, 2008 and December 31, 2011).

12. Scott Frickel et al., *Mapping Knowledge Investments in the Aftermath of Hurricane Katrina: A New Approach for Assessing Regulatory Agency Responses to Environmental Disaster,* 12 ENVTL. SCI. & POL'Y 119, 119 (2009) [hereinafter Frickel, *Mapping Knowledge*].

13. Examples of such disagreements can be seen in the cases of environmental monitoring in New Orleans after Hurricane Katrina and in northern England after Chernobyl. *See* Scott

example, critics of genetically engineered foods often argue that more research, addressing unexamined questions, must be carried out before the foods can be considered safe.[14] In a similar vein, environmental health movements typically call on government agencies to carry out research on the causes of particular diseases, expressing their concern that not enough, or the wrong kind, of research is being done.[15]

This pattern of conflict is also evident in the debate over expanding natural gas production in the Marcellus Shale. Academic researchers and professional organizations have voiced concerns about Marcellus Shale gas development, citing an overall lack of independent scientific assessments adequate to understand the possible short- and long-term environmental risks of gas development.[16] For example, environmental scientist David Velinsky points out that it is not known

> whether there is a threshold point past which a certain density of drilling activity has an impact on the ecological health and services of the watershed regardless of how carefully drilling is conducted. Past studies that have looked at particular well sites or particular incidents fail to give a picture of the chronic impacts that might be expected from drilling and especially hydraulic fracturing.[17]

Frickel & M. Bess Vincent, *Hurricane Katrina, Contamination, and the Unintended Organization of Ignorance*, 29 TECH. SOC. 181, 183 (2007) (describing the exchange between environmental groups requesting more testing after Hurricane Katrina and a regulatory agency's director responding by labeling the groups "alarmists" and "scaremongers"); Brian Wynne, *Misunderstood Misunderstandings: Social Identities and Public Uptake of Science*, *in* MISUNDERSTANDING SCIENCE?: THE PUBLIC RECONSTRUCTION OF SCIENCE AND TECHNOLOGY 19, 19–44 (Alan Irwin & Brian Wynne eds., 1996) (describing the contentious relationship between hill sheep farmers and the scientific community during a ban on farming following the Chernobyl disaster).

14. RACHEL SCHURMAN & WILLIAM A. MUNRO, FIGHTING FOR THE FUTURE OF FOOD: ACTIVISTS VERSUS AGRIBUSINESS IN THE STRUGGLE OVER BIOTECHNOLOGY 103 (2010).

15. Phil Brown et al., *Embodied Health Movements: New Approaches to Social Movements in Health*, 26 SOC. HEALTH & ILLNESS 50, 50 (2004) (referring to this kind of civic engagement as "embodied health movements").

16. *See, e.g.*, Letter from the Council of Scientific Society Presidents to federal agencies and elected officials (May 4, 2010), *available at* http://www.eeb.cornell.edu/howarth/CCSP%20letter%20on%20energy%20&%20environment.pdf.

17. Testimony on the Economic and Environmental Impacts of Hydraulic Drilling of Marcellus Shale on Philadelphia and the Surrounding Region, Hearing Before the Joint Comms. on the Env't and Transp. & Pub. Utils. of the Council of the City of Phila. (Sept. 28, 2010) (written statement of David Velinsky, Vice President for Environmental Research, Academy of Natural Sciences) [hereinafter Velinsky testimony], *available at* http://catskillcitizens.org/learnmore/ VELINSKYTEST.pdf.

The Chesapeake Bay Foundation asserts, "To date, we have not seen either a comprehensive impact assessment of drilling in the Marcellus Shale region or even careful environmental analysis for site-specific permits—steps we believe are necessary to ensure that land, air, and water resources are protected."[18] These "unknowns" about the impacts of shale gas development are among the key arguments in favor of slowing or halting further Marcellus Shale activity and they are the major reason why civil society groups are taking watershed monitoring into their own hands.

In contrast, proponents of gas development have attempted to minimize concern about watershed impacts, indicating either that no further research is necessary, or that any additional research will simply confirm that the impacts are minimal. T. Boone Pickens, for example, dismissed public concerns about watershed impacts:

> Western New York is concerned about it. They now have said, 'You're gonna frack these wells in the watershed? What? The Watershed!' They don't even know what the watershed is. That's where it rains. It rains in the watershed and then runs into a lake. And you're not gonna frack a lake or the watershed or whatever. You're fracking down 10,000 feet, two miles under the surface. But my God you say that to people, in New York, they don't know what's gonna happen to their water. Well what they need is somebody intelligent, a leader to say this is what the deal is. Don't worry. Just watch what I'm telling you, listen to what I'm saying and check the facts. That's all you have to do. It's not complicated. It's very simple [*sic*].[19]

This type of disagreement about whether more research is needed is fairly common, and a growing body of research in sociology and science and technology studies has analyzed the dynamics of such disputes, focusing on the social dimensions of "ignorance" and "unknowns."[20] There are several types of unknowns, resulting from different kinds of social processes. Matthias Gross categorizes various

18. *Water Quality Issues: Natural Gas Drilling and Marcellus Shale*, CHESAPEAKE BAY FOUND., http://www.cbf.org/page.aspx?pid=2410 (last visited Jan. 30, 2012).

19. T. Boone Pickens, BP Capital Chairman, Speech at the National Press Club (Apr. 19, 2011), *available at* http://www.c-spanvideo.org/program/TBoo (comments at 39:03).

20. *See generally* AGNOTOLOGY: THE MAKING AND UNMAKING OF IGNORANCE (Robert N. Proctor & Londa Schiebinger eds., 2008) (collecting articles discussing the study of ignorance—or "agnotology" as coined in the book).

forms of unknowns in a typology that includes nescience, non-knowledge, and negative knowledge.[21]

Nescience is a lack of knowledge about the unknown—a situation in which people are not aware of the knowledge they lack.[22] There may well be consequences of Marcellus Shale development that no one has yet considered. Awareness of the difficulty of anticipating all possible risks is a key reason why the public often distrusts experts and regulatory agencies to adequately govern new technological developments and environmental hazards.[23]

In contrast to nescience, there are two forms of specified ignorance, or absences of knowledge of which people are aware. The first is *non-knowledge*, which is "knowledge about what is not known but taking it into account for future planning."[24] In other words, non-knowledge refers to gaps in knowledge that people are aware of and seek to take into account when making decisions or planning new studies. For example, it is known that there is a lack of definitive information about how cumulative water withdrawals of the amount required for shale gas extraction will affect watershed quality, so this was among the topics that were included in an ongoing study by the U.S. Environmental Protection Agency (EPA).[25] Advocacy groups

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21. MATTHIAS GROSS, IGNORANCE AND SURPRISE: SCIENCE, SOCIETY, AND ECOLOGICAL DESIGN 68 (2010) [hereinafter GROSS, IGNORANCE AND SURPRISE]; Matthias Gross, *The Unknown in Process: Dynamic Connections of Ignorance, Non-Knowledge and Related Concepts*, 55 CURRENT SOC. 742, 751 tbl.1 (2007) [hereinafter Gross, *The Unknown in Process*] (listing categories of knowledge, unknowns, and extended knowledge).

22. Gross, *The Unknown in Process*, *supra* note 21, at 751 tbl.1.

23. *See generally* ULRICH BECK, RISK SOCIETY: TOWARD A NEW MODERNITY (Mark Ritter trans., Sage Publications 1992). In this highly influential book, Beck develops the "risk society" thesis that suggests that as an outcome of modernization, contemporary industrial societies have experienced the proliferation of new risks. Hazards resulting from new industrial processes and technological developments are difficult to measure and quantify, despite the prevailing adherence to presumably calculable risk-benefit decision-making. Indeed, risks like radiation, cancer-causing toxins, and greenhouse gases are often invisible to observers; the public is therefore increasingly dependent on scientists to characterize the nature of the risks they face. Yet in the risk society, the place of science and technology—widely seen as the source of these novel risks—is precarious. Science typically produces incomplete and contradictory knowledge about contemporary hazards. As a result, there is growing public criticism of the institutions of science and a distrust of scientific experts.

24. GROSS, IGNORANCE AND SURPRISE, *supra* note 21, at 68.

25. OFFICE OF RESEARCH & DEV., U.S. ENVTL. PROT. AGENCY, PLAN TO STUDY THE POTENTIAL IMPACTS OF HYDRAULIC FRACTURING ON DRINKING WATER RESOURCES 17 tbl.1 (2011), *available at* http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/FINAL-STUDY-PLAN-HF_Web_2.pdf.

and concerned individuals have called for delaying Marcellus Shale development until after the EPA study has been completed.[26]

The second kind of specified ignorance is *negative knowledge*, or "knowledge about what is not known but considered unimportant or even dangerous."[38] For instance, as the Pickens quote above illustrates, proponents of gas development may not view the absences of knowledge about watershed impacts as having much importance, or they may view such knowledge as threatening to their interests in developing the resource. Recently, social scientists have advanced the concept of *undone science,* which refers to "areas of research that are left unfunded, incomplete, or generally ignored but that social movements or civil society organizations often identify as worthy of more research."[27] Research communities and regulators, on the other hand, may view undone science as unimportant, not worth pursuing, or simply unrealistic to carry out. In this case, as the discussion above suggests, many critics of shale gas development argue that the watershed impacts of gas drilling should be monitored more closely. In one striking example, the Pennsylvania Department of Environmental Protection (PA DEP) responded to a citizen request for monitoring of local streams with the following statement:

> [W]e currently do not have the resources to conduct baseline testing prior to the start of drilling activities. The Department is responsible for assessing all of our waterways, and should therefore be able to document an impact that would actually cause impairment of a stream's designated use. However, it might be difficult to measure more subtle changes. We strongly encourage citizens who want to be involved in protecting their water resources to participate in volunteer monitoring programs.[28]

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26. Don Hopey, *1,200 Hear Marcellus Shale Debate*, PITTSBURGH POST-GAZETTE, Jul. 23, 2010, http://www.post-gazette.com/pg/10204/1074773-455.stm#ixzz1nueUTAUz ("Several [people in attendance] urged that a moratorium on Marcellus Shale drilling be enacted until the EPA finishes its study scheduled for the end of 2012.").

27. *See* Scott Frickel et al., *Undone Science: Charting Social Movement and Civil Society Challenges to Research Agenda Setting,* 35 SCI., TECH. & HUM. VALUES 444 (2010) [hereinafter Frickel, *Undone Science*]; *see also* Edward Woodhouse et al., *Science Studies and Activism: Possibilities and Problems for Reconstructivist Agendas*, 32 SOC. STUD. OF SCI., 297, 299 (2002); David J. Hess, *The Potentials and Limitations of Civil Society Research: Getting Undone Science Done*, 79 SOC. INQUIRY 306 (2009); David J. Hess, *Environmental Reform Organizations and Undone Science in the United States: Exploring the Environmental, Health, and Safety Implications of Nanotechnology*, 19 SCI. AS CULTURE 181 (2010).

28. Letter from Nels J. Taber, Pa. Dep't of Envtl. Prot., Northcentral Reg'l Office Dir., to private resident of Warren Center, Pa. (Oct. 13, 2010) (on file with authors).

As a result of the gap between public demands for knowledge and the information that regulatory and research communities are able to provide, civil society groups often seek to produce scientific knowledge themselves. Indeed, there are numerous examples of community struggles to discover, monitor, and protest environmental contaminants such as toxic waste and air pollution.[29] Civil society research can generate knowledge about environmental pollutants that otherwise would not be documented. In some cases, volunteer-collected data has been put to work in campaigns against polluters and for government response to environmental health problems.[30]

But why are academic and regulatory scientists failing to produce scientific knowledge that civil society groups need? Further study is needed to identify the specific forces shaping current research efforts related to Marcellus Shale development; however, the literature on the social production of knowledge and ignorance offers some potential answers. Contrary to a common assumption, addressing absences of knowledge is unlikely to be simply a matter of allowing time for science to "catch up" with a rapidly growing industry.

Some research indicates that an absence of knowledge about topics of public concern may stem from the unequal power of different social groups in processes of agenda-setting for scientific research.[31] Sociologists and historians of science have identified the institutional and cultural forces that steer disciplines or research

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29. There is a growing body of literature documenting the successes of "citizen science" efforts. *See*, *e.g.*, Phil Brown, *Popular Epidemiology and Toxic Waste Contamination: Lay and Professional Ways of Knowing*, 33 J. HEALTH & SOC. BEHAV. 267 (1992); JASON CORBURN STREET SCIENCE: COMMUNITY KNOWLEDGE AND ENVIRONMENTAL HEALTH JUSTICE (2005); S.R. Couch & S. Kroll-Smith, *Environmental Movements and Expert Knowledge: Evidence for a New Populism*, *in* ILLNESS AND THE ENVIRONMENT: A READER IN CONTESTED MEDICINE 384 (Steve Kroll-Smith et al. eds., 2000); Gwen Ottinger, *Buckets of Resistance: Standards and the Effectiveness of Citizen Science*, 35 SCI., TECH. & HUM. VALUES 244 (2010); C. Overdevest & B. Mayer, *Harnessing the Power of Information Through Community Monitoring: Insights from Social Science*, 86 TEX. L. REV. 1493 (2008).

30. Rachel Morello-Frosch et al., *Experts, Ethics, and Environmental Justice: Communicating and Contesting Results from Personal Exposure Science*, *in* TECHNOSCIENCE AND ENVIRONMENTAL JUSTICE: EXPERT CULTURES IN A GRASSROOTS MOVEMENT 93, 93–118 (Gwen Ottinger & Benjamin Cohen eds., 2011).

31. *See generally* SANDRA HARDING, IS SCIENCE MULTICULTURAL?: POSTCOLONIALISMS, FEMINISMS, AND EPISTEMOLOGIES (1998); AGNOTOLOGY: THE MAKING AND UNMAKING OF IGNORANCE, *supra* note 20; Frickel, *Undone Science*, *supra* note 27, at 446 ("Because elites set agendas for both public and private funding sources, and because scientific research is increasingly complex, technology-laden, and expensive, there is a systematic tendency for knowledge production to rest on the cultural assumptions and material interests of privileged groups.").

programs toward some questions and not others, particularly the influence of sexist and racist assumptions and the alignment of scientific fields with military or industrial priorities.[32] With respect to regulatory science, several factors may shape the nature and scope of research that is carried out, including: market, technocratic, and non-deliberative theories of administration;[33] and pressures to prioritize certain communities and geographic areas for environmental monitoring.

With respect to questions of environmental pollution, the spatial distribution of research efforts may be uneven in ways that reflect patterns of social inequality. Scott Frickel and his colleagues analyzed the "organization of ignorance" and production of "knowledge gaps" with respect to toxic pollution in post-Hurricane Katrina New Orleans.[34] Using methods of socio-spatial analysis, Frickel and his colleagues mapped the distribution of the EPA's "knowledge investments," or the "time, money, technologies, expertise, and other resources" that the agency expended on sampling and testing soil and sediment across the city.[35] Not only did this analysis reveal that knowledge investments were unevenly distributed across the city, but it also indicated that knowledge investments were highest in two types of neighborhoods: "racially diverse neighborhoods and predominantly black low-income neighborhoods containing known pre-existing environmental hazards."[36] These findings raise questions about "the social value of the distribution of [the] EPA's knowledge investments" and the adequacy of the risk information provided to

32. *See, e.g.*, Michelle Murphy, *Uncertain Exposures and the Privilege of Imperception: Activist Scientists and Race at the US Environmental Protection Agency*, 19 OSIRIS 266, 268 (2004); Paul Forman, *Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940-1960*, 18 HIST. STUD. PHYSICAL & BIOLOGICAL SCI. 149, 150–81 (1987); GERALD MARKOWITZ & DAVID ROSNER, DECEIT AND DENIAL: THE DEADLY POLITICS OF INDUSTRIAL POLLUTION 267–77 (2003); DAVID F. NOBLE, AMERICA BY DESIGN: SCIENCE, TECHNOLOGY, AND THE RISE OF CORPORATE CAPITALISM 67–324 (1979).

33. Robert F. Durant & Jerome S. Legge, *"Wicked Problems," Public Policy, and Administrative Theory: Lessons from the GM Food Regulatory Arena*, 38 ADMIN. & SOC'Y 309 (2006).

34. *See generally* Scott Frickel, *On Missing New Orleans: Lost Knowledge and Knowledge Gaps in an Urban Hazardscape*, 13 ENVTL. HIST. 643 (2008); Frickel, *Mapping Knowledge*, *supra* note 12; Frickel & Vincent, *supra* note 13.

35. Frickel, *Mapping Knowledge*, *supra* note 12, at 123–25.

36. *Id.* at 125–30.

residents of neighborhoods that received fewer investments by the EPA.[37]

In the case of Marcellus Shale gas development there is already evidence that some watersheds are receiving special protection because of the population size and political power of the people who consume the water. Namely, the New York State government has singled out the watersheds that provide water to New York City and Syracuse for an especially detailed environmental process that does not apply to the rest of the state.[38] It is reasonable to expect that watersheds that provide water to lower-income, rural (low population density), and politically disempowered populations will receive lower levels of monitoring. However, it is also possible, as discovered in the study by Frickel and his colleagues, that low-income areas with a history of environmental problems will receive greater knowledge investments because of the legacy of pollution.

The allocation of existing public resources for water quality monitoring may also be uneven in ways that reflect historically constructed and institutionalized environmental priorities. Watersheds that have already been deemed "valuable" are likely to be prioritized for water quality monitoring. This is evident, for example, in the case of the Susquehanna River Basin, which, unlike most other rivers and streams in the region, is now closely monitored for indicators of gas-drilling-related pollution.[39] A wide array of research examines the processes of social construction that result in unequally valued natural areas, landscapes, resources, or species.[40] If decisions about knowledge investments are based, in part, on beliefs about the relative value of a natural area or subject, and the

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37. *Id.*

38. Mireya Navarro, *Drilling for Gas in Catskills Watershed Restricted*, N.Y. TIMES, Apr. 24, 2010, http://www.nytimes.com/2010/04/24/science/earth/24drill.html.

39. *See Remote Water Quality Monitoring Network*, SUSQUEHANNA RIVER BASIN COMM'N, http://mdw.srbc.net/remotewaterquality/ (last visited Apr. 4, 2012).

40. Environmental historians and sociologists have observed that priorities for protection of nature stem from social processes that "construct" certain places and species as worthy of preservation, while other aspects of nature or the environment are not socially recognized as valuable. For examples of research in this vein, see generally William Cronon, *The Trouble with Wilderness; or, Getting Back to the Wrong Nature*, 1 ENVTL. HIST. 7 (1996); ABIGAIL ENTWISTLE ET AL., PRIORITIES FOR THE CONSERVATION OF MAMMALIAN DIVERSITY: HAS THE PANDA HAD ITS DAY? 1–7 (Abigail Entwistle & Nigel Dunstone eds., 2000); JOHN A. HANNIGAN, ENVIRONMENTAL SOCIOLOGY: A SOCIAL CONSTRUCTIONIST PERSPECTIVE 92–108 (Steven Yearley ed., 1995).

subsequent establishment of special protections or designations for particular watersheds, this may explain some knowledge gaps.

Government regulators may also experience pressure not to disclose environmental knowledge. Environmental justice scholar Barbara Allen has commented on the problem of "missing information" about the health impacts of environmental toxins, which stems not only from the failure to conduct suitable studies, but also from secrecy and the hiding of scientific data.[41] A central theme in the debate about hydraulic fracturing across the United States has been information disclosure. For instance, environmental and public health activists have demanded that gas-drilling companies disclose the chemical mixtures they use in drilling operations.[42] Demands for transparency reveal public frustration with regulatory agencies, and are based on the premise that necessary knowledge exists, but it is not being shared.

In summary, the reasons why regulatory science may not meet public needs for knowledge about environmental hazards are more complex than simply a lack of time or resources, although funding and staff constraints are key obstacles to comprehensive environmental knowledge. If social forces produce unknowns in the ways discussed above, efforts to remedy absences of knowledge must be responsive to the underlying social forces. With this in mind, we consider whether ongoing efforts to gather data on watershed impacts are adequate to the task of monitoring and governing shale gas industry activity.

II. WHAT DO WE KNOW ABOUT WATERSHED IMPACTS?

Numerous environmental risks of Marcellus Shale gas development have been identified by scientists and regulatory agencies. The occurrence of numerous spills and accidents would appear to support the contention that the industry is likely to have

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41. Barbara Allen, *Environment, Health, and Missing Information*, 13 ENVTL. HIST. 659 (2008); *see also* Peter Galison, *Removing Knowledge*, 31 CRITICAL INQUIRY 229 (2004); Brian Martin, *Suppressing Research Data: Methods, Context, Accountability, and Responses*, 6 ACCOUNTABILITY IN RES. 333 (1999); Stephen Zavestoski et al., *Science, Policy, Activism, and War: Defining the Health of Gulf War Veteran*, 27 SCI. TECH. & HUM. VALUES 171 (2002).

42. Lisa Song, *Secrecy Loophole Could Still Weaken BLM's Tougher Fracking Regs*, INSIDE CLIMATE NEWS (Feb. 15, 2012), http://insideclimatenews.org/news/20120215/blm-fracking-chemicals-disclosure-hydraulic-fracturing-proprietary-natural-gas-drilling?page=show; *see also* Theo Colborn et al., *Natural Gas Operations from a Public Health Perspective*, 17 HUMAN & ECOLOGICAL RISK ASSESSMENT 1039, 1049–55 (2011).

negative effects on the environment. However, extant information on gas-drilling impacts is incomplete and often contested by industry. Thus, we offer an assessment of the limits of scientific understanding and of the gaps in knowledge regarding the impacts of shale gas development.

A. Potential Impacts of Natural Gas Development

Many risks of natural gas development were discussed in detail in the *Revised Draft Supplemental Generic Environmental Impact Statement* (*Revised Draft SGEIS*) prepared by the New York State Department of Environmental Conservation (NYSDEC) in 2011.[43] Through a public scoping process, extended public comment periods, and input from engineers, geologists, and other scientists and specialists within the NYSDEC's natural resources and environmental quality programs, the *Revised Draft SGEIS* identified four main categories of possible impacts to surface water resources from horizontal drilling and high-volume hydraulic fracturing of Marcellus Shale: First, cumulative water withdrawals for drilling and fracturing. Second, storm water runoff or erosion and sedimentation from well pads; construction sites for pads, ponds, roads, and pipelines; equipment storage areas; and reclamation sites. Third, spills or releases of chemicals used in hydraulic fracturing due to tank ruptures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicular), ground fires, operational inadequacies or failures, or any other improper discharge of liquid wastes including improperly treated flowback water from the drilling or hydraulic fracturing process. And fourth, inadequate or improper disposal of drilling waste, flowback, and produced water.[44]

New York's *Revised Draft SGEIS* also identified periodic naturally occurring events, such as flooding, as a potential source of significant chemical releases to the environment, if not planned for or mitigated properly.[45] Another risk identified is the potential for

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43. N.Y. STATE DEP'T OF ENVTL. CONSERVATION, REVISED DRAFT SUPPLEMENTAL GENERIC ENVIRONMENTAL IMPACT STATEMENT ON THE OIL, GAS AND SOLUTION MINING REGULATORY PROGRAM, WELL PERMIT ISSUANCE FOR HORIZONTAL DRILLING AND HIGH-VOLUME HYDRAULIC FRACTURING TO DEVELOP THE MARCELLUS SHALE AND OTHER LOW-PERMEABILITY GAS RESERVOIRS, EXECUTIVE SUMMARY 9–13 (2011), *available at* http://www.dec.ny.gov/energy/75370.html.

44. *Id.*

45. *Id.* at 10.

surface water impacts associated with the long-term, open-pit retention of large volumes of drill cuttings containing Naturally Occurring Radioactive Materials (NORMs) and Technologically Enhanced Naturally Occurring Radioactive Materials (TENORMs) on Marcellus well pads.[46] Many of these same concerns have been further documented in reports from other municipal, state, and federal agencies, as well as from civil society organizations and academic researchers.[47] A recent scientific review article indicated that rapid expansion of natural gas drilling poses a threat to surface waters.[48]

Some anticipated watershed impacts of Marcellus Shale development have already occurred, as documented by a variety of researchers. For example, preliminary results of ongoing collaborative research between the Pittsburgh Water and Sewer Authority and the University of Pittsburgh School of Engineering have shown that Marcellus Shale flowback water is a major contributor of total dissolved solids (TDS), including bromide, to the Allegheny River.[49] In 2010, researchers from the Academy of Natural Sciences at Drexel University reported tentative findings that high-intensity gas development reduces the quality of watersheds. The study compared nine small watersheds and found:

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46. *Id.* at 13.

47. *See, e.g.*, N.Y.C. DEPT. OF ENVTL. PROT., FINAL IMPACT ASSESSMENT REPORT: IMPACT ASSESSMENT OF NATURAL GAS PRODUCTION IN THE NEW YORK CITY WATER SUPPLY WATERSHED (2009); THOMAS W. BEAUDUY, SUSQUEHANNA RIVER BASIN COMM'N, ACCOMMODATING A NEW STRAW IN THE WATER: EXTRACTING NATURAL GAS FROM THE MARCELLUS SHALE IN THE SUSQUEHANNA RIVER BASIN (2009), *available at* http://www.srbc.net/programs/docs/Marcellus%20Legal%20Overview%20Paper%20%28Beauduy%29.pdf.PDF (prepared for presentation at the 27th Annual Water Law Conference, American Bar Association, Section of Environment, Energy, and Resources); DANIEL J. SOEDER & WILLIAM M. KAPPEL, U.S. GEOLOGICAL SURVEY, U.S. DEP'T OF THE INTERIOR, WATER RESOURCES AND NATURAL GAS PRODUCTION FROM THE MARCELLUS SHALE, FACT SHEET 2009-3032 (2009), *available at* http://pubs.usgs.gov/fs/2009/3032/pdf/FS2009-3032.pdf.

48. Sally Entrekin et al., *Rapid Expansion of Natural Gas Development Poses a Threat to Surface Waters*, 9 FRONTIERS IN ECOLOGY & THE ENV'T 503, 504 (2011), *available at* http://faculty.uca.edu/sentrekin/Entrekin%20et%20al.%202011%20frontiers.pdf.

49. STANLEY STATES ET AL., BROMIDE IN THE ALLEGHENY RIVER AND THMS IN PITTSBURGH DRINKING WATER: A LINK WITH MARCELLUS SHALE DRILLING (2011), *available at* http://www.essentialpublicradio.org/sites/default/files/story/extras/2011-december/2011-12-02/state-studysmall.pdf. After elevated TDS levels were found in the Monongahela River watershed, including the Alleghany River, the Pennsylvania Environmental Quality Board implemented changes to regulations permitting discharge of treated wastewater to Pennsylvania surface waters. Wastewater Treatment Requirements, 40 Pa. Bull. 4835 (Aug. 21, 2010).

> [T]here was a significant difference between high-density drilling locations and locations with no or low-density drilling. Water conductivity was almost twice as high in the high-density sites as it was in the low-density and reference sites, while the number of both salamanders and sensitive insects were approximately 25% reduced.[50]

There have also been documented incidents of drinking water contamination resulting from drilling activities, potentially indicating aquifer contamination.[51] Methane migration through aquifers as a result of drilling and hydraulic fracturing is a well-documented problem in areas undergoing shale gas development.[52] For example, the PA DEP found that bubbles occurring along the western bank of the Susquehanna River in Bradford County, Pennsylvania, were methane gas, the result of Marcellus drilling two miles away.[53] Aquifer contamination would impact not only well water, but also surface water, since streams are fed by groundwater.

B. Limits of Scientific Knowledge About Gas Development Impacts

Research on the impacts of gas development on surface water is challenging, as ecologists have pointed out:

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50. Velinsky testimony, *supra* note 17.

51. OHIO DEP'T OF NATURAL RES., DIV. OF MINERAL RES. MGMT., REPORT ON THE INVESTIGATION OF THE NATURAL GAS INVASION OF AQUIFERS IN BAINBRIDGE TOWNSHIP OF GEAUGA COUNTY, OHIO (2008), *available at* http://www.dnr.state.oh.us/Portals/11/bainbridge/report.pdf.

52. *See, e.g.*, Stephen G. Osborn et al., *Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing*, 108 PROCEEDINGS NAT'L ACAD. SCI. 8172 (2011); Laura Legere, *EPA: Dimock Water Supplies 'Merit Further Investigation,'* SCRANTON TIMES-TRIBUNE, Dec. 31, 2011, http://thetimes-tribune.com/news/epa-dimock-water-supplies-merit-further-investigation-1.1251334#axzz1jisTwFlv (discussing a high-profile case in the Marcellus shale, where eleven homes in Dimock, Pennsylvania were left with explosive levels of methane in their water wells after nearby drilling for Marcellus shale gas began).

53. Press Release, Pa. Dep't of Envtl. Prot., DEP Monitors Stray Gas Remediation in Bradford County Requires Chesapeake to Eliminate Gas Migration (Sept. 17, 2010), *available at* http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=14274&typeid=1. As of December 2011, the gas is still bubbling from the river at this spot. This is not an isolated event. New gas seeps have been reported in recent years near drilling of Marcellus shale wells in creeks, lakes, and ponds throughout northeastern and southwestern Pennsylvania. *Seeps, Leaks, & Spills*, *supra* note 11. While it is dramatic to the eye, what ecological and public health impact, if any, methane migration has on surface water quality remains an as yet unanswered scientific question. ROBERT B. JACKSON ET AL., RESEARCH AND POLICY RECOMMENDATIONS FOR HYDRAULIC FRACTURING AND SHALE-GAS EXTRACTION (2011), *available at* http://www.nicholas.duke.edu/cgc/HydraulicFracturingWhitepaper2011.pdf.

> Quantifying the effects of natural gas development on surface waters in shale basins is difficult because multiple companies often work in the same geographical area and use different fracturing techniques (e.g. varied and often proprietary composition of fracturing fluids), resulting in uncoordinated timing of infrastructure development and well fracturing. In addition, the degree to which these companies adhere to best management practices, such as buffer strips and erosion control devices, varies among companies as a result of the differing regulations among states and agencies. Furthermore, wells occur across human-impacted watersheds with characteristics that may confound our ability to attribute effects from gas-well development.[54]

In addition to these research difficulties, reports of contamination are typically challenged by gas-drilling companies and there are often conflicting reports from different agencies and researchers. An example of this can be seen in the case of a spill that occurred in Bradford County on April 19, 2011. The incident took place in Leroy Township when the wellhead valve flange connection failed at the Atgas 2H gas well owned by Chesapeake Appalachia, LLC (Chesapeake).[55] This wellhead failure occurred during hydraulic fracturing into the Marcellus formation and resulted in an off-site release (past the containment system) of over 10,000 gallons of well fluids containing a mixture of materials being used in hydraulic fracturing at the time and produced waters. The fluids were contained on the well pad by the afternoon of April 20 (over twelve hours after the initial failure) and the well was under permanent control by April 25.[56] Before they were contained, however, the chemicals broke through the earthen berm containment system, flowed into a freshwater pond and agricultural fields, and eventually flowed into Towanda Creek, a tributary of the Susquehanna River.[57] Amphibians in a nearby pond were found dead after the release.[58]

Two separate reports on the Atgas spill, one done by a private contractor hired by the gas well owner, and another done by a federal

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54. Entrekin et al., *supra* note 48, at 509.

55. SAIC ENERGY, ENV'T & INFRASTRUCTURE, LLC, GROUNDWATER & ENVIRONMENTAL SERVICES, INC., ATGAS INVESTIGATION INITIAL SITE CHARACTERIZATION AND RESPONSE APRIL 19, 2011 TO MAY 2, 2011, ATGAS 2H WELL PAD PERMIT NO. 37-015-21237 LEROY TOWNSHIP, BRADFORD COUNTY, PA (Aug. 30, 2011) [hereinafter SAIC].

56. Eric Hrin, *Chesapeake Informed of Maryland's Intent to Sue*, TOWANDA DAILY REVIEW (May 6, 2011), http://thedailyreview.com/news/chesapeake-informed-of-maryland-s-intent-to-sue-1.1142711.

57. *Id.*

58. *Id.*

government agency, provided conflicting findings. The private contractor report, commissioned and paid for by Chesapeake determined that there was no ground water or surface water contamination because of the spill.[59] A second report by the Agency for Toxic Substances & Disease Registry (ATSDR),[60] which focused solely on the potential pathways of environmental contamination that could affect human health, found that at least one private drinking water well adjacent to the spill was contaminated, possibly as a result of the chemical spill from the Atgas well.[61] In light of this finding, the ATSDR report went on to say that the agency would be conducting further tests and research to determine the exact cause of the contamination and any possible human health impacts.[62] In the meantime, Chesapeake maintains that there was "no effect whatsoever" on surface water.[63]

If studies of the aftermath of catastrophic spills produce contradictory findings, it is even more challenging to produce consensus on the long-term, non-point, and cumulative impacts of Marcellus Shale gas development on watershed health. In response to mounting national public and scientific concerns regarding the impact of hydraulic fracturing on human health and the environment, Congress recently instructed the EPA to conduct a scientific study to investigate the possible relationships between hydraulic fracturing and impacts to drinking water.[64] This national study is expected to provide a scientific assessment of the risks to drinking water by hydraulic fracturing techniques used in the oil and gas industry across the United States.[65] Congressional hearings in anticipation of the EPA

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59. SAIC, *supra* note 55, §§ 6.3–6.4.

60. The ATSDR is a federal public health agency of the U.S. Department of Health and Human Services. AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, http://www.atsdr.cdc.gov (last visited Feb. 21, 2012).

61. AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, U.S. DEP'T OF HEALTH & HUMAN SERVS., HEALTH CONSULTATION-CHESAPEAKE ATGAS 2H WELL SITE 19–20 (2011).

62. *Id.* at 20–21.

63. Hrin, *supra* note 56; *see also* Melissa Troutman, *Shoveling Water: The Life of a Predrill Test*, THE PUBLIC HERALD (Dec. 19, 2011), http://www.publicherald.org/archives/14617/investigative-reports/energy-investigations/fracking-energy-investigations/ (discussing Chesapeake's conclusion that the pre-drill test did not reveal pre-existing conditions).

64. H.R. REP. NO. 111-316, at 109 (2009) (Conf. Rep.); H.R. REP. NO. 111-180, at 99–100 (2009).

65. OFFICE OF RESEARCH & DEV., U.S. ENVTL. PROT. AGENCY, PLAN TO STUDY THE POTENTIAL IMPACTS OF HYDRAULIC FRACTURING ON DRINKING WATER RESOURCES 1 (2011) [hereinafter EPA PLAN].

study revealed a great deal of disagreement over the appropriate boundaries of the study, with shale gas development proponents pushing for an extremely narrow focus that would treat many potential avenues for water pollution as outside of the appropriate reach of the EPA's analysis.[66]

In the end, the EPA settled on a fairly broad scope for the study. While the focus of the study is on drinking water and groundwater, four of the five questions the EPA plans to answer relate to the entire hydraulic fracturing water lifecycle and the consequences of this lifecycle on surface water quality and quantity.[67] The report will specifically evaluate the impact of surface water withdrawals, surface spills during mixing of hydraulic fracturing fluids, surface spills of flowback and produced water, and inadequate treatment of all types of waste waters from the hydraulic fracturing process.[68] Case studies will be conducted in three Pennsylvania counties already undergoing shale gas development (Washington, Bradford, and Susquehanna) in order to inform and provide regional context for the larger EPA study.[69]

Even when the EPA's study has been completed, people in communities affected by gas development may feel as though there is still "undone science" to carry out. Large-scale studies like the one being conducted by the EPA are extremely important for producing generalizable knowledge about the environmental impacts of shale gas development and for informing public policy. However, studies that strive for universal knowledge cannot address every particular concern of watershed residents, such as questions about how legacies of pollution may interact with new sources of contamination from gas development, or how to protect particular places that have local value (for example, small, unnamed streams that are nevertheless important to locals). There is often a large gap between scientific research (which aims to produce generalizable knowledge about the likelihood that shale gas development causes watershed degradation) and local watershed monitoring (which aims to produce detailed knowledge of particular bodies of water).

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66. *Review of Hydraulic Fracturing Technology and Practices: Hearing Before the H. Comm. on Sci., Space, and Tech.*, 112th Cong. (2011), *available at* http://www.gpo.gov/fdsys/pkg/CHRG-112hhrg66221/pdf/CHRG-112hhrg66221.pdf.

67. EPA PLAN, *supra* note 65, at ix.

68. *Id.* at ix, xi.

69. *Id.* at 58–63.

While the EPA is carrying out its investigation, other regulatory agencies are increasing their efforts to monitor watersheds for contamination. In 2010, the Susquehanna River Basin Commission (SRBC), in collaboration with the U.S. Geological Survey (USGS) and the Susquehanna River Heartland Coalition for Environmental Studies,[70] deployed a continuous monitoring network that would specifically address surface water quality changes in areas of increased gas development activities.[71] This method utilizes remote monitoring devices to collect data from a sample of sites in order to draw conclusions about the state of water quality. The goal of the monitoring network, according to the SRBC, is both to collect baseline water quality data on conductivity, pH, temperature, turbidity, oxygen demand, and flow rates, and to collect real-time data on sudden changes in any of these indicators in order to provide information to scientists and regulatory agencies responding to contamination events.[72] In addition, the data is available to the public on an Internet site as a resource for citizens who are monitoring the impacts of gas developments in their local waterways.[73] Initial funding for this monitoring network came from the USGS and East Resources, Inc., an oil and gas exploration and development company acquired in July 2010 by Royal Dutch Shell PLC. These funds were used to purchase the continuous monitoring equipment and set up the

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70. The Susquehanna River Heartland Coalition for Environmental Studies (SRHCES) was organized in 2004 "to promote collaboration in research, provide environmental education, improve water quality, and address other environmental concerns related to the Susquehanna River Watershed," with its primary geographic focus being the West Branch and lower North Branch of the watershed. SRHCES includes "faculty from seven area institutions of higher education, representatives from government agencies, and community organizations." *About SRHCES*, SUSQUEHANNA RIVER HEARTLAND COAL. FOR ENVTL. STUDIES, www.srhces.org/Pages/About SRHCES.aspx (last visited Feb. 10, 2012).

71. SUSQUEHANNA RIVER BASIN COMM'N, PROPOSED NETWORK DESIGN (2009), *available at* www.srbc.net/programs/docs/networkdesign.pdf. This network was an expansion and upgrade of their existing "Early Warning System" or EWS. *Id.* The geographic focal points of this new monitoring and EWS network are areas within the northern and central sections of the Susquehanna River watershed where gas developments are happening now, areas where gas development is not yet happening (control sites), and sensitive headwater streams. *See* SUSQUEHANNA RIVER BASIN COMM'N, INFORMATION SHEET: REMOTE WATER QUALITY MONITORING NETWORK (2011), *available at* http://www.srbc.net/pubinfo/docs/RWQMN Info Sheet 10-18-11.pdf.

72. *Id.*

73. *Id.*

real-time data acquisition system.[74] However, the on-going maintenance of the monitoring network and equipment is the responsibility of the SRBC. This maintenance is critical to the long-term utility of the network's baseline record and Early Warning System (EWS) functions. Given recent budget cuts to agencies such as the USGS,[75] the question remains whether there will be consistent and reliable government funding at the state and federal levels to not only maintain the monitoring and EWS systems equipment, but to also maintain staffing levels at the SRBC that are sufficient to handle the new data being acquired through the system.

Reports of radioactive material and other hazardous substances in water being treated in municipal, publicly operated treatment works (POTWs) led the EPA to request that the PA DEP increase its monitoring.[76] In response, the PA DEP outlined special new monitoring requirements that would be expected of POTWs. These requirements include quarterly monitoring for TDS, pH, alkalinity, chloride, sulfate, and bromide and annual monitoring for gross alpha, radium 226 and 228, and uranium.[77] The analysis of the samples will be conducted at an accredited laboratory using EPA-approved

74. Rona Kobell, *Gas Firm to Fund Monitoring of Waterways in Marcellus Shale Area: East Resources to Contribute $750,000 Needed to Set Up SRBC Network*, CHESAPEAKE BAY JOURNAL (2010), www.bayjournal.com/article.cfm?article=3749.

75. Interior, Environment, and Related Agencies Appropriations for 2011: Hearings Before the Subcommittee on Interior, Environment, and Related Agencies of the Committee on Appropriations, 111th Cong. 302–62 (2011) (statements of Public Witnesses), *available at* http://democrats.appropriations.house.gov/images/stories/pdf/ienv/Hearing_Volumes/FY11_Int_Pt7.pdf; Denise Richardson, *USGS Plans to Shut Off Area Stream Gauges*, THE DAILY STAR (Dec. 8, 2011), thedailystar.com/localnews/x440785388/USGS-plans-to-shut-off-area-stream-gauges (reporting that several USGS stream gauges in New York would be shut off due to budget cuts).

76. Letter from Shawn M. Garvin, Region III Adm'r, U.S. Envtl. Prot. Agency, to Michael Krancer, Acting Sec'y, Pa. Dep't of Envtl. Prot. (Mar. 7, 2011), *available at* http://www.epa.gov/region3/marcellus_shale/PADEP_Marcellus_Shale_030711.pdf (recognizing that data collected to date has shown that wastewater from Marcellus shale gas operations contains variable and high concentrations of radionuclides, organic chemicals, metals, and total dissolved solids that could pose a danger to human health and aquatic ecosystems, and requesting that the Department provide the EPA with a plan to address these dangers, including "(i) a list of the community water systems that will be required to conduct expedited monitoring, (ii) sampling parameters and frequency, and (iii) schedule for initiating and completing these actions").

77. Letter from Lisa D. Daniels, Operations Monitoring & Training Div. Chief, Pa. Dep't of Envtl. Prot., to public water suppliers across Pennsylvania (Mar. 11, 2011) (on file with authors).

methods and the results will be reported to the PA DEP.[78] None of the results of this monitoring have been shared with the public, except through consolidated annual "consumer" reports such as those of Pennsylvania American Water, the private corporation that runs the largest POTWs within the Monongahela watershed.[79]

In summary, despite efforts by a variety of regulatory agencies and academic scientists to examine the environmental impacts of shale gas development, there are still notable absences of essential environmental knowledge. Large-scale research projects remain in preliminary stages, while regulatory monitoring—basic data-gathering about the release of pollutants from shale gas developments—is not happening in many places where developments are occurring, resulting in spatial knowledge gaps (or, areas where there is little to no data about water quality). That is, while the SRBC's remote monitoring project is admirable, it is limited to the Susquehanna River Basin and leaves most headwater streams unmonitored. Even when data is being gathered, as is the case of water treatment facilities on the Monongahela River, it is not always being reported to the public. For each of these reasons, volunteer watershed monitoring is an appealing option for communities that are concerned about Marcellus Shale gas development.

III. FILLING THE GAPS WITH VOLUNTEER WATERSHED MONITORING

In the past few years, volunteer watershed monitoring has gained prominence as a way to increase knowledge about the impacts of Marcellus Shale gas development.[80] Numerous non-profit and

78. *Id.*

79. *See Water Quality Reports*, PA. AM. WATER, http://www.amwater.com/paaw/customer-service/water-quality-reports.html (last visited Mar. 18, 2012).

80. Much of our discussion here about volunteer watershed monitoring efforts is based on information gathered by the authors through a sociological research study funded by the U.S. National Science Foundation. The research began in August 2010 and is expected to continue through August 2013. Data was collected through a variety of methods, including a survey of county conservation districts and volunteer watershed protection groups in New York and Pennsylvania; interviews with representatives of watershed monitoring training organizations; participation in a volunteer water monitoring project (Cayuta-Catatonk Water Watch) for one year; a review of materials provided by water monitoring training organizations (such as brochures, websites, training manuals, and research protocols); a review of newspaper reports and other media coverage of volunteer monitoring efforts; and observation of a variety of trainings and conferences on watershed monitoring [hereinafter Kinchy & Perry NSF Research].

academic organizations have initiated efforts to train volunteers to monitor the impacts of shale gas operations on surface water resources. For example, the Pennsylvania Council of Trout Unlimited created a stream surveillance program called the Coldwater Conservation Corps. Since the program began in early 2010, 200 volunteers have been trained, and organizers hope to increase that number to 500 in 2012. The goal is to have monitors on 1000 streams.[81]

Similar volunteer watershed monitoring programs aimed at evaluating the surface water impacts of Marcellus Shale gas developments in New York and Pennsylvania have been started by other non-profit and academic organizations including the Izaak Walton League of America, Alliance for Aquatic Resource Monitoring (ALLARM), Pine Creek Headwaters Protection Group, Community Science Institute, Delaware Riverkeeper, Wilkes University, and the University of West Virginia. Responding to the growing interest and participation in volunteer monitoring across Pennsylvania, in 2011 a group of researchers at Pennsylvania State University (Penn State) received a National Science Foundation (NSF) grant to compile and analyze volunteer-generated data about the watershed impacts of Marcellus Shale gas development.[82] According to geoscientist Susan Brantley, the principal investigator on the project, "In the future, many monitoring networks of all kinds will need to include citizen scientists to keep costs down, and research scientists will need to learn to use such networks to [achieve] the best outcome."[83]

Volunteer water monitoring has historically been a common type of participatory environmental assessment activity.[84] Generally speaking, however, most watershed monitoring projects in the United States have been initiated and coordinated by professional scientists with the goal of producing knowledge that can be used in academic

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81. Telephone Interview with Katy Dunlap, E. Water Project Dir., Trout Unlimited (Nov. 1, 2011) (notes on file with authors).

82. Cheryl Dybas, *Can Marcellus Shale Development and Healthy Waterways Sustainably Coexist? National Science Foundation Sustainability Research Coordination Network Is Providing Answers*, NAT'L SCI. FOUND. (Dec. 19, 2011), http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=122543&WT.mc_id=USNSF_8.

83. *Id.*

84. William Deutsch et al., *Group Dynamics and Resource Availability of a Long-Term Volunteer Water-Monitoring Program*, 22 SOC'Y & NAT. RES. 637, 638 (2009).

and regulatory work.[85] In contrast, the emerging efforts to monitor the impacts of Marcellus Shale gas development on watersheds are frequently initiated by activists, grassroots community organizations, and advocacy groups rather than professional scientists. They are sometimes supported (but not directed) by scientific experts at universities or private laboratories. Typically, efforts to monitor the impacts of Marcellus Shale development on watersheds involve a capacity-building group (such as Trout Unlimited, ALLARM, or Wilkes University) that trains, advises, and provides other services to locally organized groups of volunteers. Funding for these projects comes from a variety of sources, depending on the group. Some capacity-building organizations receive public funding and others count on foundation funding to support their watershed monitoring activities.[86]

A. *Rationales for Volunteer Monitoring*

There are at least three ways that volunteer water monitoring fills knowledge gaps about the impacts of Marcellus Shale development. First, knowledge gaps may be filled in spatially, as volunteer efforts are mobilized around bodies of water where public agencies and academic scientists are not gathering data. That is, volunteers monitor watersheds that public agencies neglect to study or do not study intensively enough to satisfy public needs. As one academic scientist who has worked with volunteer water monitors explained,

> [R]ecognizing that governmental agencies charged with environmental oversight have limited manpower and resources, individuals and watchdog groups are stepping forward to take action. Not only do these additional eyes and ears on the ground provide important field surveillance assistance, but individuals trained to use basic monitoring equipment can generate valuable preliminary water-quality data.[87]

Second, volunteer efforts are likely to ask questions and define problems differently than regulatory agencies and academic scientists.

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85. *E.g.*, Rick Bonney et al., *Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy*, 59 BIOSCIENCE 977 (2009).

86. Kinchy & Perry NSF Research, *supra* note 80.

87. Md. Khalequzzaman & John H. Way, *Beech Creek Watershed Monitoring*, CLINTON CNTY. NATURAL GAS TASK FORCE (Mar. 10, 2011), *available at* http://www.clintoncountypa.com/resources/CCNGTF/pdfs/articles/3.10.11%20-%20Beech%20Creek%20Watershed%20Monitoring.pdf.

Consequently, they gather data to answer questions that are different from those posed by regulators and academic scientists. For example, the Pine Creek Waterdogs, discussed below, combine chemical testing of streams with observations of industry behavior, potentially offering a more holistic assessment of watershed threats.[88] Third, volunteer efforts may provide data about water quality in areas where regulators and other scientists are also monitoring, but not releasing data publicly. For instance, in Waynesburg, Pennsylvania, municipal water treatment authorities are monitoring stream quality, but they are not regularly releasing monitoring data to the public. In response, volunteers are monitoring the same streams and reporting the data to the EPA.[89]

In addition to filling knowledge gaps, another reason volunteers cite for engaging in water monitoring activities is that they hope to deter the gas industry from polluting waterways through illegal dumping and careless procedures. A guide to water monitoring developed by ALLARM describes one of the two major objectives as: "Prevention of future environmental impact through the continuing presence of watchful residents."[90] The idea here is that by making the industry aware that volunteers are keeping an eye on their actions, industry actors will be less likely to engage in activities that could harm watershed health.

B. Procedures for Volunteer Watershed Monitoring

There are no standard procedures for volunteer watershed monitoring, and there is significant diversity among monitoring projects. Some capacity-building organizations offer sophisticated scientific research tools, such as laboratories, and a variety of water testing techniques, including quality control and quality assurance procedures. These projects require extensive training for volunteers and careful record keeping. Others emphasize relatively low-tech monitoring techniques that are fairly simple to use and that can be

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88. Kinchy & Perry NSF Research, *supra* note 80.

89. *See, e.g.*, *Citizen Watershed Monitors*, IZAAK WALTON LEAGUE OF AM. HARRY ENSTROM CHAPTER, https://sites.google.com/site/harryenstromchapter/citizen-watershed-monitors (last visited Mar. 19, 2012) (providing access to other water-quality monitoring reports).

90. CANDIE C. WILDERMAN & JINNIETH J. WOODWARD, MARCELLUS SHALE GAS EXTRACTION: A STUDY DESIGN AND PROTOCOL FOR VOLUNTEER MONITORING 5 (2010) [hereinafter ALLARM], *available at* http://www.marcellus-shale.us/pdf/Stream-Monitoring.pdf.

readily adopted by a large number of volunteers. Some projects are relatively decentralized, with local volunteer groups managing their data, while others are centralized, with volunteers submitting data and observations to the capacity-building organization.[91]

There are numerous ways to assess stream quality, including visual observations, analysis of macroinvertebrates in a stream, and chemical testing. Some tools are electronic—such as TDS meters (a popular device for detecting impacts of gas development)—and some are chemical—such as chemical titration kits that measure dissolved oxygen. Electronic meters are manufactured by a variety of companies and vary in their quality and ease of use. This is one way that volunteer water monitoring projects vary. Additionally, the self-identified goals of these projects range widely, and volunteers seek to use the data they collect in a variety of different ways. Three examples of volunteer watershed monitoring projects illustrate elements of the diversity among these efforts.

1. Cayuta-Catatonk Water Watch: Citizen Initiated, Scientist Mentored

The Cayuta-Catatonk Water Watch (CCWW) was formed in early 2010 by a group of people living in and near Van Etten, a small community south of the Finger Lakes Region in New York.[92] The group approached the Community Science Institute (CSI), a nonprofit organization, for assistance in developing a water-monitoring project for the Cayuta and Catatonk creeks that run through several New York counties and feed into the Susquehanna River. The CSI maintains a laboratory certified by the New York State Department of Health to conduct water quality tests that meet regulatory standards. Steve Penningroth, the director of the CSI, has a Ph.D. in biochemical sciences and was formerly a professor at Cornell University. He started the CSI in 2000, and since that time, the CSI has worked with volunteers in the Cayuga Lake watershed to determine whether the lake and its tributaries are safe for swimming,

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91. These observations are based on a preliminary analysis of survey results as well as discussions with participants in a variety of watershed monitoring projects in New York and Pennsylvania.

92. Abby J. Kinchy, notes from Cayuta-Catatonk Water Watch Meetings and Training Sessions (Aug. 2010–Sept. 2011) (on file with authors) [hereinafter CCWW Notes]. Some information presented in this section draws on a printed Community Science Institute promotional brochure. For more information on the Community Science Institute, see CMTY. SCI. INST., http://www.communityscience.org/ (last visited Apr. 4, 2012).

to examine the effectiveness of wastewater treatment plants, and to monitor the impacts of fertilizer runoff and other pollution problems. The CSI currently works with eight independent groups of volunteers who have been trained to monitor water quality at over 125 stream and lake locations. Volunteers collect water samples and conduct chemical analyses; some groups also do aquatic insect monitoring. The results of water quality tests are checked in the CSI's laboratory, and the CSI provides ongoing technical support. The CSI also manages the data collected by volunteers and provides an online, searchable database.[93]

In early discussions, members of the CCWW expressed a variety of reasons for doing volunteer watershed monitoring. Some felt that it was important to develop hard data to strengthen their "emotional" objections to gas development. Others said monitoring the creeks would show the industry that they are serious about environmental protection. Many agreed that the government had been "compromised" and that citizens were obligated to "hold the line" and hold the gas industry accountable for the pollution it causes. Participants in early planning meetings discussed the shortcomings of existing water monitoring efforts by the SRBC, saying that there were few monitoring stations in the area and that they are expensive to operate and keep properly calibrated.[94]

The CCWW began gathering baseline data about the quality of the Cayuta and Catatonk watersheds beginning in early 2011. On a monthly basis, volunteers test the quality of water at twenty-five different monitoring sites in the two watersheds, gathering data on temperature, pH, dissolved oxygen, conductivity, and total hardness. The group considers these to be "red flag" indicators of contamination. In addition, the CSI laboratory periodically carries out a more comprehensive analysis of stream samples.[95]

Shale gas development is not currently occurring in these watersheds, but the purpose of the monitoring project is to gather baseline data about the quality of the watersheds, to enable the group to track long-term changes, and to identify pollution events if shale development proceeds in New York State. The CCWW's plan is to report findings to public officials and gas companies if pollution is

93. CCWW Notes, *supra* note 92.

94. *Id.*

95. *Id.*

identified, and, if necessary, to collaborate with larger organizations to sue New York State or gas companies under the Clean Water Act.[96] Penningroth explained that under the Clean Water Act, citizens can bring lawsuits if they discover that surface water has been degraded.[97] Toward that end, the CCWW emphasizes collecting scientifically credible evidence. Extensive training, support by a certified laboratory, and well-developed quality control and quality assurance procedures are signature parts of the CCWW–CSI collaboration.

2. Waterdogs: Citizen Initiated and Implemented

The Pine Creek Headwaters Protection Group, located in Potter and Tioga Counties, Pennsylvania, was formed in 1987 to address the impacts of acid mine drainage from abandoned coal mines in the Grand Canyon region of north-central Pennsylvania.[98] In 2009, the group realized there was a shortfall in PA DEP field personnel and thus a growing need for more monitoring of the possible impacts of shale gas development on high-quality trout streams in Tioga, Potter, Bradford, Sullivan, and Susquehanna Counties. In partnership with the Tioga County Conservation District, the group began conducting training workshops for volunteers to be "watch dogs" over waterways and shale gas-drilling sites. In Tioga and Potter Counties these volunteers came to be known as the "Pine Creek Waterdogs," and in other parts of Pennsylvania simply as the "Waterdogs."[99]

The rationale for training volunteer Waterdogs, according to the Pine Creek Headwaters Protection Group, is that the PA DEP does not have sufficient field personnel to keep up with all of the activities of the gas industry as it rapidly expands across the state.[100] Their trainings are designed to provide citizens with basic information to

96. *Id.*

97. *Id.*; *see* 33 U.S.C. § 1365(a) (2006) (creating a private cause of action for citizens alleging a violation of effluent standards or limitations, or of administrative orders respecting such limitations).

98. Laura Legere, *Citizen Training for Spotting Drilling Problems Criticized by Natural Gas Industry*, THE TIMES-TRIBUNE (Dec. 1, 2009), http://thetimes-tribune.com/news/citizen-training-for-spotting-drilling-problems-criticized-by-natural-gas-industry-1.455817#ixzz1hfYrQDXJ.

99. *Id.*

100. *Become a Pine Creek Waterdog: Citizen Monitoring the Marcellus Shale*, RESPONSIBLE DRILLING ALLIANCE, http://responsibledrillingalliance.org/index.php/get-involved/pine-creek-waterdog (last visited Feb. 13, 2012).

assist the PA DEP in this monitoring by educating volunteers on standard shale gas industry operations, on how to differentiate between routine and abnormal industry operations, and on how to report problems when they are spotted. The Pine Creek Waterdogs have posted signs along the streams they are monitoring to let the public, agencies, and gas companies know they are watching.[101]

Volunteer Waterdogs use simple TDS meters and visual documentation to detect possible changes in water quality near gas development sites. Visual documentation of streams and creeks is done with photographs and written observations of changes in the color, consistency, odor, and behavior of surface waterways. Fish and amphibian kills, discharge of unregulated or unknown materials into surface waters, and suspicious activity, including dumping of drilling and hydraulic fracturing wastes into waterways, are also tracked and reported. As of September 2011, they have trained an estimated 600 volunteers to monitor local creeks and streams throughout Pennsylvania.[102]

3. ALLARM: Scientist Developed, Citizen Implemented

ALLARM began in 1986 as a project of the Environmental Studies Department at Dickinson College in Carlisle, Pennsylvania. Candie Wilderman, an environmental science professor, wanted to provide a way to monitor acid rain deposition impacts on Pennsylvania streams and creeks by training students—and eventually volunteer watershed organizations—to go out and collect the data.[103] In its acid rain monitoring, ALLARM worked closely with the federal government and state government to set up a system of reporting and even established its own state-certified laboratory at Dickinson College. Through its years of working with volunteer watershed groups across Pennsylvania, ALLARM recognized the need to strengthen volunteer capacity to do the “citizen science” required to assist agencies in their monitoring work. Consequently, it has built up a solid repertoire of trainings on quality assurance and

101. E-mail from Jim Weaver, Liaison, Pine Creek Headwaters Prot. Grp., to Simona L. Perry (Sept. 28, 2011, 10:44 EST) (on file with author).

102. *Id.*

103. Candie C. Wilderman et al., Top Down or Bottom Up? ALLARM’s Experience with Two Operational Models for Community Science, Proceedings of the 2004 Nat’l Monitoring Conf., Chattanooga, TN May 17–20, Nat’l Water Quality Monitoring Council, *available at* http://acwi.gov/monitoring/conference/2004/proceedings_contents/13_titlepages/posters/poster_235.pdf.

quality control measures, field sampling protocols, as well as community organizing and volunteer recruitment and retention that it conducts in workshop settings with watershed groups.[104] ALLARM considers itself a training and capacity-building organization for Pennsylvania and the mid-Atlantic States' watershed organizations with the mission to "[e]nhance local action for the protection and restoration of Pennsylvania watersheds by empowering communities with scientific knowledge and tools to implement watershed assessments."[105]

Starting in 2009, ALLARM began to field phone calls and emails from its watershed group partners who were asking questions about how the Marcellus Shale development was impacting local waterways and what measures they could take to monitor and report any impacts. In late 2009, ALLARM started developing a "protocol" for Marcellus Shale water quality monitoring using their knowledge of citizen science best practices and their previous model of capacity-building across the state, which included working with established local watershed organizations.[106] This protocol uses TDS and conductivity as "red flag" parameters to indicate possible contamination, which then triggers the collection of samples to test for "signature chemicals" whose presence can identify flowback water from hydraulic fracturing as the source of contamination. ALLARM chose barium, strontium, and total alpha as the signature chemicals to test.[107] The protocol training manual was piloted in Bradford County, a county in northeastern Pennsylvania experiencing a rapid increase in the number of shale gas wells and related infrastructure.

In the fall of 2010, ALLARM released its final "Marcellus Shale Volunteer Monitoring Manual."[108] As of December 16, 2011, ALLARM has partnered with Trout Unlimited, Mountain Watershed Association, Delaware Riverkeeper, and the Pennsylvania Association for Sustainable Agriculture to conduct twenty-nine workshops in southwestern, northwestern, and northeastern counties

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104. *Id.*

105. ALLARM, *supra* note 90, at 1.

106. *Id.* at 2.

107. Faith Zerbe & Candie Wilderman, *Monitoring Impacts of New Gas-Drilling Technologies*, 21 THE VOLUNTEER MONITOR 3 (2010), *available at* http://water.epa.gov/type/rsl/monitoring/upload/volmon21no1.pdf.

108. ALLARM, *supra* note 90, at 1 n.1.

of Pennsylvania, during which they have trained approximately 650 volunteers.[109]

IV. ASSESSMENT: THE PROMISE OF VOLUNTEER MONITORING

Volunteer watershed monitoring holds potential not only to address the "unknowns" associated with shale gas development, but also for communities to mobilize to protect their local environments. Apart from volunteer projects, there are frequently no other recent sources of data about surface water quality in particular streams and water bodies. Large-scale, generalizable studies of the cumulative watershed impacts of gas development have yet to be completed, and water monitoring by government authorities is geographically limited. Therefore, impacts of shale gas development may easily go unnoticed by those with the authority to regulate the industry. In this context, data collected by volunteers may be extremely valuable. Furthermore, the process of forming a monitoring group, learning about the local watershed, and carrying out stream studies is likely to contribute to the development of scientific literacy, environmental concern, and social solidarities that are necessary for the ongoing success of grassroots efforts to protect the environment and public health. In addition, the nascent alliances between professional scientists and volunteer monitoring groups are likely to be important in future legal struggles over the impacts of gas development. For all of these reasons, volunteer watershed monitoring should be broadly encouraged and supported with public and private funds.

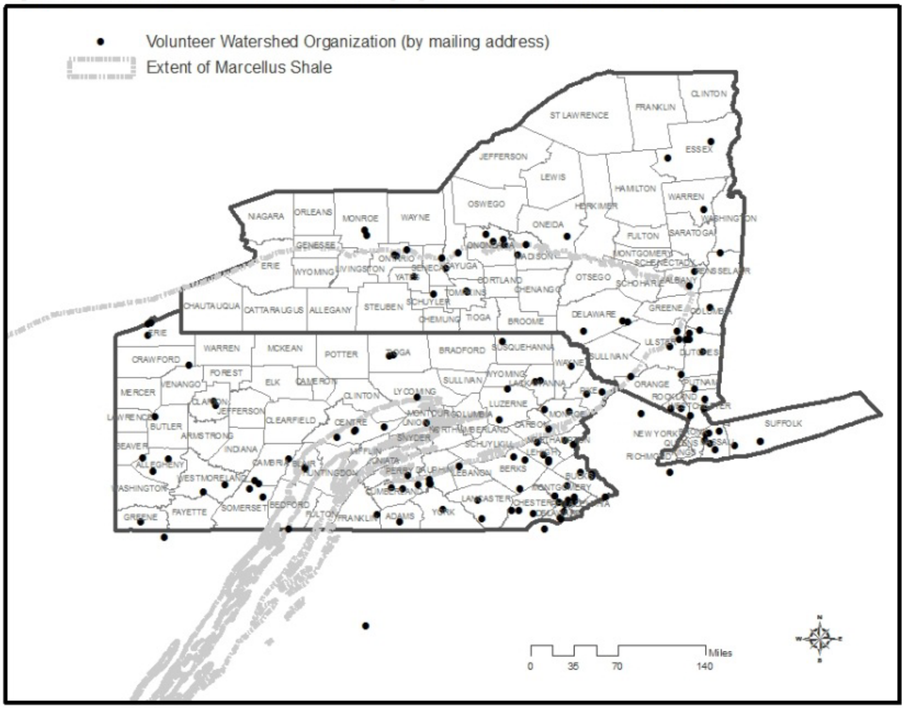
If volunteer watershed monitoring is to serve its full potential, there are several areas of concern that must be addressed. There are many obstacles to creating and sustaining volunteer efforts. In a preliminary search for volunteer watershed monitoring organizations, we discovered that there are few projects with headquarters in northwest and north-central Pennsylvania, compared to numerous known projects with mailing addresses in the more densely populated parts of the state (Figure 1).[110] Although we do not yet have sufficient data about the activities of each organization to know where

109. Telephone Interview with Julie Vastine, Director of ALLARM (Dec. 2011) (notes on file with authors).

110. Based on preliminary geocoded maps of the mailing addresses of volunteer watershed monitoring and capacity-building organizations, which were identified using a database of watershed organizations maintained by the EPA and additionally populated with watershed monitoring organizations identified by key informants involved in watershed monitoring work.

volunteer monitoring activities are taking place (since activities may extend into regions far from the contact mailing address), it appears that there are many counties that lack an organizational base for such efforts.

Figure 1. Dispersion of Volunteer Organizations in Relation to Marcellus Shale



Why might some counties have less water monitoring activity than others? A recent study of a long-term volunteer water monitoring program with groups in several counties of Alabama found that a "[l]ack of human resources, social organization, discretionary wealth, and environmental consciousness clearly hindered the development of monitoring groups in rural areas," thus leaving some regions unmonitored.[111] Socio-demographic factors including population density, race, education, and income are likely

111. Deutsch et al., *supra* note 84, at 647.

to play a role in determining the success of volunteer watershed monitoring, as are factors such as access to resources and existing organizational infrastructure (for example, local watershed associations and supportive funding agencies).

We expect resource issues to be of central importance. Key resources are water testing materials, free time for participation in monitoring activities, and access to scientific allies who can both support the design and implementation of a watershed monitoring project and access necessary materials and resources. Furthermore, even in areas where capacity-building resources are available, volunteer efforts can be difficult to sustain. Representatives from a variety of capacity-building organizations have informed us that it can be difficult to continue volunteer interest in monitoring and reporting data after the initial training.

There are also significant questions that remain unanswered about how data collected by volunteers will be used. There have been no assurances that regulatory agencies like the PA DEP will use or respond to volunteer-collected data. Indeed, one informant from a capacity-building group in Pennsylvania said that a PA DEP representative told her that the agency would probably not immediately respond to findings reported by volunteers and that the DEP could not use data collected by volunteers for enforcement purposes.[112] Beyond regulators, academic scientists may also find the data collected by volunteers to be problematic. As indicated earlier, water monitoring practices vary widely. From the perspective of researchers seeking generalizable knowledge, volunteers' knowledge about local watershed health may be difficult to reconcile with the need to identify direct causal relationships between shale gas development and changes in watershed quality. Furthermore, because of the diversity of goals and the variability in access to resources, water monitoring projects differ in terms of the parameters measured, the frequency of measurement, the technologies used, and the criteria for selecting measurement sites. Lack of standardization will make it difficult to make comparisons across watersheds or to piece together a causal assessment of the impacts of shale gas development.

There are also reasons to question the assumption that a volunteer presence will promote "good behavior" on the part of the

112. Abby J. Kinchy & Simona L. Perry correspondence with watershed monitoring expert (Apr. 2011) (notes on file with authors).

gas industry. Volunteer monitoring is likely to have a deterrent effect only if the following two conditions are met: (1) volunteer observations are widely considered to be strong and credible evidence that particular industry actors have caused pollution, and (2) there are strong and enforceable penalties for causing pollution. In our view, neither of these criteria is currently being met. There is no indication that regulatory agencies will be responsive to volunteer-collected data, although this could change. Furthermore, the penalties for pollution remain relatively low and are sometimes passed on to the numerous subcontractors that serve the industry, rather than being imposed on the major gas development companies. In response to an April 2011 report on the fines issued by the PA DEP, representatives from the Sierra Club and PennFuture said the DEP's fines were too low, merely "background noise" and a "cost of doing business" for gas companies, rather than a deterrent to harmful activities.[113] If this is the case, simply observing the polluting behaviors of a gas development company is not likely to significantly change its behavior.

Various case studies indicate that alliances with universities can enable volunteer environmental monitoring groups to overcome the challenges of developing and maintaining useful civil society research.[114] However, community members and scientists may not entirely agree on priorities, problem definitions, and ideas about what good research looks like. For example, a recent announcement that Cornell Cooperative Extension researchers were seeking participants in a study of well water quality was met with criticism by the head of the CSI and local activists, who pointed out that the design of the study did not meet the needs of landowners.[115] In addition, we anticipate that volunteers and academic scientists may clash over funding issues; indeed, we have frequently heard critics of Marcellus Shale gas development say that they distrust academic scientists who are funded either by industry or government. As one research

113. Sean D. Hamill, *What Fines Reveal About Drilling in State*, PITTSBURGH POST-GAZETTE, Apr. 17, 2011, http://www.post-gazette.com/pg/11107/1139961-503-0.stm#ixzz1iPTVO4pS.

114. *See*, *e.g.*, PHIL BROWN & EDWIN J. MIKKELSEN, NO SAFE PLACE: TOXIC WASTE, LEUKEMIA, AND COMMUNITY ACTION 165–66 (1990); Beth Savan et al., *Volunteer Environmental Monitoring and the Role of the Universities: The Case of Citizens' Environment Watch*, 31 ENVTL. MGMT. 561, 562 (2003).

115. E-mail from Steve Penningroth, Exec. Dir. Cmty. Sci. Inst., to various environmental email lists (Dec. 1, 2011, 11:19 AM) (on file with authors).

scientist put it, "Whatever answer we come up with, there may be people who assume we were bought off."[116]

Finally, we are concerned about the broader implications of the growing enthusiasm for volunteer water monitoring. The value of civil society research should not be understated. However, to the extent that civil society research replaces regulatory science, it can be considered a form of privatization, consisting of the shift of responsibilities from the domain of government agencies to the private sector and civil society associations. Indeed, studies of volunteer water monitoring efforts often point to the diminishing capacity of public agencies as a major reason for initiating volunteer efforts.[117] In this regard, volunteer water monitoring guided and coordinated by non-governmental organizations (NGOs) resembles what international development scholars have often called "NGOization"—the increasing tendency for state actors to contract with NGOs to work on problems that the state is unwilling or incapable of addressing directly.[118] In the case of monitoring impacts of Marcellus Shale gas development, most groups involved in volunteer efforts are not directly under contract with states; generally speaking, watershed groups "pick up the slack" without funding or explicit agreements with state actors. However, as noted above, the

116. Susan Phillips, *Research on Marcellus Drilling Hampered by Lack of Data, Lack of Funding, and Concerns of Bia*s, STATEIMPACT (Oct. 24, 2011), http://stateimpact.npr.org/pennsylvania/2011/10/24/research-on-marcellus-drilling-hampered-by-lack-of-data-lack-of-funding-and-concerns-of-bias/ (quoting Richard Horwitz); *see also* Reid R. Frazier & Olivia Garber, *Corporate Funding of Marcellus Shale Studies at Universities Raises Alarms*, PITTSBURGH POST-GAZETTE, Nov. 7, 2011, http://www.post-gazette.com/ pg/11311/1188150-503.stm.

117. *See* Dana O'Rourke & Gregg P. Macey, *Community Environmental Policing: Assessing New Strategies of Public Participation in Environmental Regulation*, 22 J. POL'Y ANALYSIS & MGMT. 383, 390 (2003); Savan et al., *supra* note 114, at 561–62.

118. For discussions of the forces driving NGO-ization, see generally Kamat Sangeeta, *The Privatization of Public Interest: Theorizing NGO Discourse in a Neoliberal Era*, 11 REVIEW OF INT'L POLITICAL ECON. 155–76 (2004); Sonia E. Alvarez, *Advocating Feminism: The Latin American Feminist NGO "Boom"*, 1 INT'L FEMINIST J. OF POLITICS 181–209 (2010). McCarthy and Prudham, astute observers of the "rolling back" of environmental regulation, note that citizen "participation" (often without significant capacity or authority) is among other pervasive changes associated with neoliberalism. They observe the growth of "increasingly voluntarist, neo-corporatist regulatory frameworks involving non-binding standards and rules, public-private co-operation, self-regulation, and greater participation from citizen coalitions, all with varying degrees of capacity and accountability." James McCarthy & Scott Prudham, *Neoliberal Nature and the Nature of Neoliberalism*, 35 GEOFORUM 275, 276 (2004).

PA DEP "strongly encourage[s]" citizens to get involved in watershed monitoring programs and directs people to ALLARM.[119]

CONCLUSION AND RECOMMENDATIONS

We are deeply concerned about the possibility of cumulative watershed degradation in rural areas that have not been prioritized for regular monitoring and protection by government agencies. Water pollution is a serious matter for communities that depend on local fresh water sources, whether for consumption, watering livestock, irrigating fields, fishing, or recreation. Lack of knowledge about pollutants can lead to dangerous health consequences and harm to biodiversity. Proponents of Marcellus Shale gas development often dismiss environmental concerns as unsubstantiated, sometimes offering counter-evidence to suggest that spills and other incidents do not have negative or lasting effects or that the effects are too infrequent to matter. In a regulatory context that places the burden of proof on the victims of pollution, rather than the producers of pollution (as would be the case under the "precautionary principle"[120]), information about water quality is of key importance to victims in affected communities.

In this context, volunteer watershed monitoring is a vitally important source of locally relevant environmental knowledge. However, given the obstacles to implementing comprehensive watershed monitoring by volunteers, and the foreseeable challenges associated with interpreting volunteer-collected data, volunteer watershed monitoring is clearly not an adequate replacement for regulatory oversight of industry behavior.

When the burden of environmental monitoring is shifted onto volunteers, individuals and civil society organizations must shoulder the expenses of monitoring equipment and spend considerable time being trained and gathering data. Not all communities will have the resources to be able to organize and sustain such an effort. If watershed monitoring is important to environmental protection, as it appears to be, then principles of environmental justice and fairness would indicate that investments in monitoring should be distributed

119. Letter from Nels J. Taber, Reg'l Dir., Northcentral Reg'l Office, Pa. Dep't of Envtl. Prot., to William Ferullo (Oct. 13, 2010).

120. James Cameron & Juli Abouchar, *The Precautionary Principle: A Fundamental Principle of Law and Policy for the Protection of the Global Environment*, 14 B.C. INT'L & COMP. L. REV. 1, 22 (1991).

equally among communities affected by Marcellus Shale gas development. This could be accomplished by providing public funds to county conservation districts, cooperative extension offices, and capacity-building organizations to support training and ongoing staff support for civil society research. During the administration of Governor Tom Ridge (1995 to 2001), the PA DEP supported and kept track of volunteer watershed monitoring through the Citizens' Volunteer Monitoring Program in the Bureau of Watershed Management.[121] This program could be revived and expanded, with a staff that is dedicated to building relationships with local watershed organizations and to assisting with the coordination and compilation of data. As noted earlier, the National Science Foundation has already begun to support an effort at Penn State to compile volunteer-collected data. This is an important step, but long-term support for sustaining county- and local-level projects will be necessary if investments in producing watershed knowledge are to be more evenly distributed across the region.

Furthermore, if volunteer-collected data is to have a role in governing the shale gas industry, it is essential to develop a thoughtful resolution to the tension between generalizable and locally-specific knowledge. As environmental justice scholar Gwen Ottinger has pointed out, civil society researchers increase their credibility among regulators when they use standard protocols for data collection and reporting.[122] However, standardization can diminish the capacity of volunteers to critique and offer alternatives to problematic, ineffective, or locally insensitive protocols used by regulators. We advocate a holistic approach to watershed monitoring and management related to Marcellus Shale development. This might include bottom-up, community-based assessment of research needs, matched with top-down political, technical, and financial support from government scientists, academic researchers, and public funding agencies. Volunteer groups can and should serve as more than simply unpaid assistants for research efforts that are planned and designed by experts; they can offer greater understanding of environmental

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121. PA DEP conducted surveys of volunteer watershed groups across the state from 1995 to 1997 and developed a "Statewide Directory of Citizens' Volunteer Monitoring Programs." *Monitoring Program Initiatives*, PA. DEPT. OF ENVTL. PROT., http://www.portal.state.pa.us/portal/server.pt?open=514&objID=554213&mode=2 (last visited Mar. 19, 2012).

122. Gwen Ottinger, *Buckets of Resistance: Standards and the Effectiveness of Citizen Science*, 35 SCI., TECH. & HUMAN VALUES 244, 264–66 (2009).

problems at the local scale and insights about how regulatory and academic science can better meet public needs.